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Chemical amelioration of solonetzic soils at the Provincial Tree Nursery, Oliver, Alberta

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CHEMICAL AMELIORATION OF SOLONETZIC SOILS AT THE PROVINCIAL TREE NURSERY, OLIVER, ALBERTA

BY

I.K. EDWARDS

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ABSTRACT

Most of the soils at the Provincial Tree Nursery at Oliver are medium- to fine-textured. They are affected either by high salinity or by solonetzic characteristics (compact sodium-enriched B horizon). Because growth of conifer seedlings on these soils is substandard and cost of production is high, the feasibility of chemical amelioration was investigated.

Soil set in acrylic columns in the laboratory was leached with solutions of ammonium nitrate, ammonium sulphate, calcium sulphate, ferrous sulphate, and aluminum sulphate in an attempt to remove excess salts and to increase the rate of water movement. Movement of water through the soil was extremely slow. Although NH_4NO_3 and $(NH_4)_2SO_4$ removed more salt than nursery water alone, use of such amendments did not seem practical from an operational viewpoint. The affected soils should be used for growing deciduous species that are more tolerant of fine-textured, sodium-enriched soils.

RESUME

La plus grande partie des sols de la pépinière provinciale de Oliver sont de texture fine à moyenne. Ils subissent l'influence soit d'une salinité élevée, soit des caractéristiques solonetziques (horizon B compacts enrichis de sodium). La croissance des semis de résineux en de tels sols est inférieure à la normale et les coûts de production sont élevés. L'auteur a étudié la possibilité d'améliorer le sol chimiquement.

Au laboratoire, un sol placé en des colonnes (tubes) acryliques fut lessivé avec des solutions de nitrate d'ammonium, de sulfate d'ammonium, de sulfate de calcium, de sulfate ferreux et de sulfate d'aluminium pour tenter d'enrayer l'excès de sel et d'augmenter le taux de mouvement de l'eau. Le mouvement de l'eau pénétrant le sol fut extrêmement lent. Bien que le NH_4NO_3 et le $(NH_4)_2SO_4$ aient enlevé plus de sel que l'eau de la pépinière seule, l'utilisation de tels amendements n'a pas semblé pratique du point de vue opérationnel. Les sols atteints devraient plutôt servir à la croissance d'espèces feuillues tolérant mieux les sols à texture fine, et enrichis de sodium.

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INTRODUCTION

Total production area at the Provincial Tree Nursery at Oliver, Alberta is approximately 108 ha[1], 70% of which was acquired in 1962 (Hillson 1971). A soil survey report of the Edmonton area (Bowser *et al.* 1962a) indicated that the nursery was situated entirely on medium-textured soils. They were mapped as an Eluviated Black to Orthic Black Chernozem (Ponoka loam), an Orthic Black Chernozem (Malmo silt loam), and a Black Solodized Solonetz (Wetaskiwin silt loam), that developed on alluvial lacustrine and lacustrine parent material.

Growth of conifer stock was substandard and costs were high; the poorest results occurred on much of the newly acquired land, a block comprising about 62 ha (Fig. 1, Fields 11-25). Since this block formed a substantial portion of the total production area, there was great interest in analyzing the problem and suggesting possible solutions. In an interim soil survey of the nursery (Massey and Carson 1972), it was found that sloughs, solonetzic soils, and saline soils accounted for as much as 60% of this particular block of land. The solonetzic soils were identified as belonging to the Wetaskiwin series and ranged in texture from silt loam to silty clay. The coarser and more suitable Peace Hills sandy loam (an Orthic Black Chernozem) amounted to less than 10% of the area.

Loamy sands and light sandy loams are most suitable for producing conifer seedlings (Stoeckeler and Jones 1957). Slow drainage, flooding, frost heaving, and compaction by mechanized equipment are some of the problems associated with medium- to fine-textured soils. They are difficult to work because they usually dry to form hard clods, and seedlings often suffer root injury during lifting. Moreover, solonetzic soils are characterized by adverse physical and chemical properties. They have a hard, blocky sodium (Na)-enriched B horizon that limits root penetration and in which hydraulic conductivity is extremely low, and a calcareous, saline C horizon (Cairns 1961, Bowser *et al.* 1962b, Cairns and Bowser 1969). High salinity of the subsoil inhibits root growth because of high osmotic pressure of the soil solution (United States Salinity Laboratory Staff 1954).

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[1] 1 ha = 2.47 acres

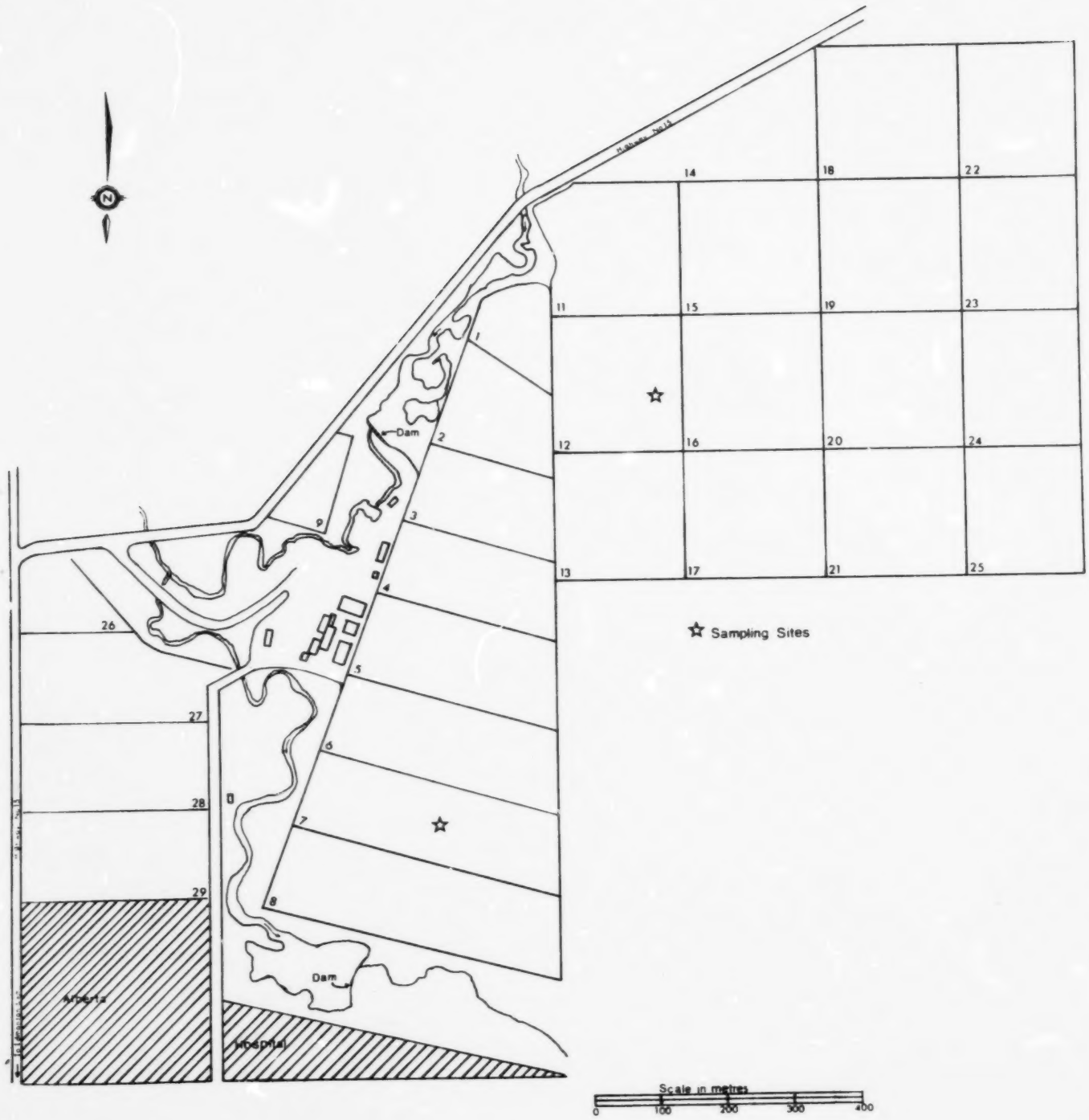

Figure 1. Field layout of the Provincial Tree Nursery, Oliver, Alberta

Solonetzic soils have been ameliorated by a combination of various practices such as drainage and irrigation, chemical treatment, fertilization, deep tillage, and proper choice of crops to be grown (Abraham and Bocskai 1971, Bowser and Cairns 1967, Cairns 1962, Cairns 1970, Cairns and van Schaik 1968, and United States Salinity Laboratory Staff 1954). The objectives of this study were to determine, in the laboratory, the effectiveness of different chemicals as ameliorants of the saline alkali soil at the nursery and to assess the possibilities for reclamation within the context of production of bare-root conifer stock.

MATERIALS AND METHODS

SITE DESCRIPTION

At the nursery, soil was sampled from each genetic horizon of two profiles selected to represent a Black Solonetz (Field 12) and, for comparison, an Orthic Chernozem (Field 7). The solonetzic area (Field 11-25) is gently undulating with slopes of 1-5%, mostly in an east-west direction. Depressions are frequently sloughs, most of which remain wet for a significant portion of the year. Level to depressional areas are sometimes flooded after rainfall or irrigation, and although they become dry within a few days, they act as sites of salt accumulation. The profile sampled in the solonetzic area was located near the crest of a knoll to avoid discharge or runoff effects.

The site of the chernozemic profile is almost level with a downward slope of less than 2% towards the west. It is well drained except for occasional low spots that collect water for some hours after irrigation. It is part of the earlier-developed portion of the nursery and therefore has been cropped and fertilized for about 10 years longer.

SOIL ANALYSIS

The samples representing both soil subgroups were air-dried, ground to pass a 2-mm sieve, and analyzed for physical properties--texture and available water capacity (AWC)--and chemical characteristics: pH; electrical conductivity (EC); organic matter (OM); phosphorus (P); nitrate

nitrogen (NO_3-N); water-soluble calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K); chloride (Cl); sulphate (SO_4); carbonate (CO_3); bicarbonate (HCO_3); ammonium acetate (NH_4OAc)-extractable Ca, Mg, Na, and K; exchangeable hydrogen (H); and cation exchange capacity (CEC). Subsamples of the dried, ground solonetzic soil were used in the leaching study described below. Bulk density (BD) and hydraulic conductivity (HC) were determined on soil cores that were removed intact from each horizon.

Texture was determined by the hydrometer method (Bouyoucos 1962), and AWC was the difference in soil moisture contents determined at equilibrium tensions of 33 and 1500 kPa using a ceramic plate extractor (Black *et al.* 1964). Soil reaction (pH) and EC were determined in soil-water paste and saturation extract, respectively (United States Salinity Laboratory staff 1954). Organic matter was determined by the Walkley-Black method (Jackson 1960), P by the Watanabe and Olsen (1965) method, and NO_3-N by the phenol-disulphonic acid method (Jackson 1960). Water-soluble Ca, Mg, Na, and K were determined in the saturation extract by atomic absorption spectrophotometry, SO_4 by turbidimetry (Chesnin and Yien 1951), Cl by titration with silver nitrate (Jackson 1960), and CO_3 and HCO_3 by titration (Rainwater and Thatcher 1960). Ammonium acetate was used to extract Ca, Mg, Na, and K (Jackson 1960), and the cations were determined by atomic absorption spectrophotometry. Exchangeable hydrogen was titrated after extraction with ammonium acetate (Atkinson *et al.* 1958), and CEC was by the sodium acetate method (Bower *et al.* 1952). Bulk density and HC were determined as described by Black *et al.* (1964).

WATER ANALYSIS

Water from the irrigation supply (a creek with a dam across it) at the nursery was analyzed for pH, EC, total dissolved solids, Ca, Mg, Na, K, Cl, SO_4, CO_3, and HCO_3 according to standard methods (Rainwater and Thatcher 1960).

LEACHING STUDY

Air-dried, ground (2-mm) soil from each horizon of the solonetzic soil was used to fill columns constructed of 7.6-cm segments of acrylic tubing (5.1 cm i.d.) that were machined to fit snugly together. In filling,

each segment was tapped repeatedly until soil volume remained constant. Final bulk density was 1.2 g/cm^3. An organic sealant was used to prevent leakage. Soil from each horizon filled two segments that were then assembled to give a model profile (Fig. 2) with 15.2 cm each of the Ap, Bnt, and Cskl horizons in that order for a total column height of 45.6 cm. A fine mesh (0.35-mm) polyethylene screen was attached to the bottom of the lowest segment to prevent soil from falling out. Finally, a 250-ml flask fitted with an 8.0-cm funnel was placed beneath the column to collect leachate.

Six columns were constructed. Soil in the first one was leached with water from the nursery supply and acted as control. Soil in each of the other columns was leached with nursery water in the presence of ammonium nitrate (4.37 g NH_4NO_3), ammonium sulphate (3.60 g $(NH_4)_2SO_4$), calcium sulphate (4.69 g $CaSO_4 \cdot 2H_2O$), ferrous sulphate (7.59 g $FeSO_4 \cdot 7H_2O$), or aluminum sulphate (5.73 g $Al_2(SO_4)_3 \cdot 16H_2O$). The weight of each chemical was that calculated as being required to displace 6 milliequivalents (me)* of Na from the soil. In each case, the chemical was mixed with 100 ml nursery water and added to the columns. As percolation occurred, more water was added to the columns to maintain a 5-cm hydraulic head. Leachate samples were analyzed for pH, EC, Ca, Mg, Na, and K in a manner similar to the water sample above.

RESULTS

PHYSICAL PROPERTIES

The solonetzic soil was much higher in clay (71-86%) than the chernozem (23-36%), and clay increased with depth rather than decreased as in the chernozemic soil (Table 1). This textural difference affected other physical properties. The moisture retained at tensions of 33 and 1500 kPa was greater for the finer-textured soil. Available water capacity decreased in the chernozem as sand content increased. Bulk density was much higher in the solonetz, and within this profile increased most sharply between the Ap and Bnt horizons, indicating the compactness of the subsoil. Hydraulic conductivity was much lower in the solonetz, reflecting its compact structure, particularly in the deeper horizons.

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* This was approximately the mean value of NH_4OAc-extractable Na in the three horizons used in the leaching study.

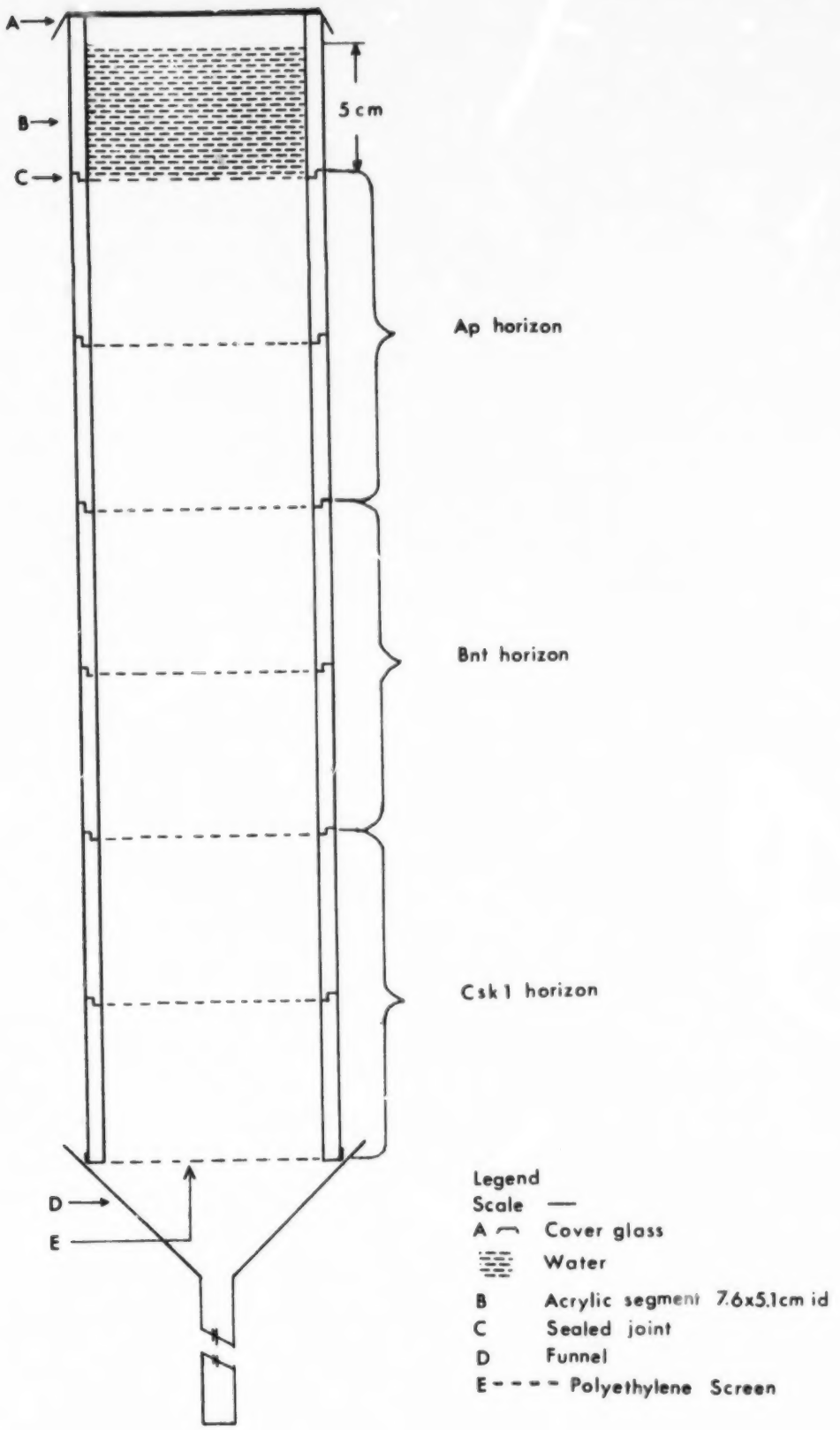

Figure 2. Assembly of a column for leaching.

Table 1. Physical properties of two soil subgroups at the Provincial Tree Nursery, Oliver

Soil Subgroup	Horizon/ Depth, cm	Sand %	Silt %	Clay %	Texture*	% Moisture 33 kPa	% Moisture 1500 kPa	AWC† %	BD† g/cm³	HC† cm/h
Black Solonetz (Field 12)	Ap 0-20	12.7	16.6	70.7	C	49.6	27.5	22.1	1.3	0.6
	Bnt 20-40	9.6	10.0	80.4	C	47.2	25.9	21.3	1.7	<.1
	Cskl 40-60	16.3	9.0	74.7	C	38.0	21.4	16.6	1.6	<.1
	Csk2 60-90	4.3	10.0	85.7	C	43.8	24.1	19.7	1.8	<.1
Orthic Black Chernozem (Field 7)	Ap 0-25	47.0	17.2	35.8	SC	33.7	14.7	19.0	1.2	6.8
	Bm 25-58	72.3	5.1	22.6	SCL	15.3	7.2	8.1	1.0	nd**
	BCk 58-64	71.9	5.1	23.0	SCL	11.4	4.8	6.6	1.1	nd

* Texture: C = Clay, SC = Sandy clay, SCL = Sandy clay loam.

† AWC = Available water, BD = Bulk density, HC = Hydraulic conductivity.

** Not determined.

CHEMICAL PROPERTIES

The surface horizons of both soils were slightly acid, whereas deeper horizons of the solonetz were moderately alkaline and those of the chernozem were mildly alkaline (Table 2). Salinity expressed by EC was low throughout the chernozem and decreased with depth. Conductivity values higher than 4 dS/m indicated high salinity (United States Salinity Laboratory Staff 1954). In the solonetz, EC increased with depth, reflecting poorer drainage. Analysis of the saturation extract for water-soluble constituents showed that in the solonetzic soil, Na and SO_4 were the principal cation and anion respectively. Magnesium, though lower than Na, was higher than Ca. Saturation extracts of the chernozem were lower in all constituents and, as normally expected, Ca was the major cation. No soluble carbonate was found in any of the extracts. Sodium adsorption ratio (SAR) was much higher in the solonetzic soil. Organic matter and P were generally higher in the solonetz, but the greatest differences were in the surface horizons. Both soils had similar concentrations of NO_3-N.

In the solonetz (Table 3), Mg was the principal cation extracted by ammonium acetate from the Ap and Bnt horizons, whereas Ca was predominant in the Csk horizons. Calcium was the major cation extracted from the chernozem. Sodium as a percentage of total extractable cations was much higher in the solonetz than in the chernozem. The percentage increased from 13.6 in the Ap horizons to 19.8 in the Bnt but decreased in the Csk horizons. In the chernozem, Na as a fraction of extractable cations was only 1-3%.

WATER QUALITY

The water from the irrigation supply at the nursery was moderately alkaline and high in soluble salts as expressed by EC (0.814 dS/m, Table 4). Water with EC values above 0.750 dS/m should be used only on land with good drainage (United States Salinity Laboratory Staff 1954). The predominant salts were bicarbonate and sulphate of calcium and magnesium. Sodium adsorption ratio was only 0.87, indicating low sodium hazard.

Table 2. Chemical properties of two soil subgroups at the Provincial Tree Nursery, Oliver

Soil Subgroup	Horizon/ Depth, cm	SP*	pH*	EC* dS/m	Soluble Cations - me/100 g					Soluble Anions - me/100 g				SAR**	OM %	NO_3-N ppm	P ppm
					Ca	Mg	Na	K	Total	Cl	SO_4	HCO_3	Total				
Black Solonetz	Ap 0-20	80.5	6.5	1.48	0.06	0.26	1.06	0.03	1.38	0.15	0.94	0.28	1.37	9.4	6.8	16.3	24.1
	Bnt 20-40	109.6	8.1	2.02	0.12	0.42	2.38	0.03	2.95	0.30	1.97	0.73	3.00	13.8	2.1	15.2	7.2
	Csk1 40-60	87.2	8.0	9.09	2.15	4.36	4.65	0.05	11.21	0.12	10.81	0.21	11.14	8.7	1.3	15.5	1.9
	Csk2 60-90†	105.2	8.1	12.31	2.82	7.61	12.56	1.00	23.99	0.25	22.57	0.26	23.08	17.0	1.1	11.1	1.7
Orthic Black Chernozem	Ap 0-25	54.5	6.4	1.05	0.40	0.19	0.03	0.01	0.63	0.07	0.29	0.05	0.41	0.3	0.7	20.5	7.5
	Bm 25-58	35.4	7.6	0.88	0.19	0.12	0.01	tr	0.32	0.05	0.21	0.03	0.29	0.1	0.5	10.6	1.7
	BCk 58-64	30.2	7.8	0.75	0.14	0.08	0.01	tr	0.23	0.03	0.20	0.04	0.27	0.1	0.4	6.3	1.7

* Saturation Percentage or % moisture in the soil paste before extraction; pH and EC were determined in the soil paste and saturation extract, respectively.

** Sodium Adsorption Ratio is an index of sodium hazard. If soluble cations are expressed in me/ℓ, $SAR = Na/\sqrt{(Ca + Mg)/2}$.
Soluble cations (me/ℓ) = Soluble cations (me/100 g) x 1000/SP.

† This sample also contained crystalline deposits of sodium sulphate.

Table 3. Extractable cations and cation exchange capacity (CEC) of two soil subgroups at the Oliver nursery

Soil Subgroup	Horizon/ Depth, cm	NH_4OAc-Extr. Cations - me/100 g						Na % of Total Cations	Ca/Na Ratio	CEC* me/100 g
		Ca	Mg	Na	K	H	Total			
Black Solonetz	Ap 0-20	10.70	22.00	6.18	1.16	5.40	45.44	13.6	1.7	44.22
	Bnt 20-40	15.50	19.62	8.88	0.89	NIL	44.89	19.8	1.7	43.75
	Csk1 40-60	91.30	16.13	5.81	0.68	NIL	113.92	5.1	15.7	27.37
	Csk2 60-90	66.00	20.42	8.76	0.74	NIL	95.92	9.1	7.5	33.15
Orthic Black Chernozem	Ap 0-25	20.90	3.73	0.75	0.44	2.70	28.52	2.6	27.9	30.24
	Bm 25-58	14.20	3.40	0.58	0.24	NIL	18.42	3.1	24.5	19.10
	BCk 58-84	15.30	2.67	0.52	0.24	NIL	18.73	1.3	29.4	14.56

* Determined by the sodium acetate method to avoid interference by $CaCO_3$ and gypsum (Bower *et al.* 1952). In calcareous soils, the sum of extractable cations includes some soluble Ca and therefore exceeds CEC.

Table 4. Chemical analysis of Nursery water - Oliver, Alberta

pH	8.10
Electrical conductivity (dS/m)	0.814
Dissolved solids (ppm)	584
Hardness as $CaCO_3$ (ppm)	388
Alkalinity as $CaCO_3$ (ppm)	292
Calcium (me/ℓ)	4.55
Magnesium (me/ℓ)	3.79
Sodium (me/ℓ)	1.78
Potassium (me/ℓ)	0.24
Carbonate (me/ℓ)	NIL
Bicarbonate (me/ℓ)	5.64
Sulphate (me/ℓ)	4.63
Chloride (me/ℓ)	0.46
Sodium adsorption ratio (SAR)*	0.87

* $SAR = Na/\sqrt{(Ca + Mg)/2}$.

LEACHING STUDY

Movement of water through soil in the columns was extremely slow. Only the control, NH_4NO_3, and $(NH_4)_2SO_4$ columns yielded enough leachate for analysis after several weeks. The first collection of leachate occurred five days after leaching began (Table 5). This represented an average flow rate of 0.1-0.2 ml/h. The rate of movement through the column decreased with time and was the same in all columns. Leachate pH was similar in all cases. Electrical conductivity was highest in leachate from the $(NH_4)_2SO_4$ column and lowest in that from the control, but the latter still contained substantial amounts of salt. Further analysis of leachate showed that K concentration was lowest of the cations in all samples. Nursery water removed Ca, Mg, and Na at similar rates, but after 90 days of leaching, greater amounts of Na and Mg than of Ca were removed from columns leached with NH_4NO_3 and $(NH_4)_2SO_4$.

DISCUSSION

PHYSICAL AND CHEMICAL PROPERTIES

Physical and chemical properties of the chernozem contrast with those of the solonetzic soil and explain why seedling production, although not satisfactory, has always been better on the former. The solonetz is more dense, and in addition to its finer texture, possesses a hard, compact Bnt horizon. Data on other solonetzic soils in Alberta (Peters 1973) indicated that they contained less clay and had a lower BD than the solonetz found at the nursery. The finest-textured soil, a Black Solonetz (Duagh series) that developed on fine-textured lacustrine sediments, contained less clay in each horizon (41-44% in the Ah, 61-74% in the Bnt, and 30-32% in the Csk), compared to the solonetz found at Oliver. Bulk density was consequently lower in the Duagh soil, 1.5 g/cm^3 for the Bnt, compared to 1.7 g/cm^3 for the Bnt horizon of the solonetz described here. The higher BD of the solonetzic soil compared to the chernozem accounted for the extremely low HC (<0.1 cm/h, Table 1). Bowser *et al.* (1962b) and van Schaik and Pawluk (1973) reported HC values of zero for the Bnt horizons of some solonetzic soils. Moderate HC values were in the 2.0-6.3 cm/h range (Black *et al.* 1964). On this basis, HC of the Ap horizon was suboptimal.

Table 5. Flow rate and analysis of leachate collected from columns

Leaching Agent	Time Elapsed days	Total Vol. Collected ml	pH	EC dS/m	Ca	Mg	Na	K
					me/ℓ			
Control (Nursery water)	5	18	8.0	5.93	33.7	30.3	20.1	0.8
	30	63	8.0	5.67	46.1	27.4	23.7	0.8
	90	209	7.8	6.86	40.9	35.2	33.4	1.0
NH_4NO_3	5	20	7.9	12.13	41.3	82.2	127.6	2.3
	30	76	8.0	14.09	61.4	125.2	145.3	2.7
	90	237	7.9	14.90	33.1	88.1	106.5	1.8
$(NH_4)_2SO_4$	5	15	8.2	17.38	49.9	114.6	147.1	2.1
	30	55	8.1	18.59	44.7	128.7	155.6	2.3
	90	268	8.3	20.86	30.2	166.9	180.7	2.7

The profile examined in this study fitted the description of a solonetzic soil (Bowser and Cairns 1967) with its friable A horizon, impermeable, sodic B horizon, and saline, calcareous C horizon. Predominance of Na and SO_4 among water-soluble constituents (Table 2) was similar to most of the other solonetzic soils in Alberta irrespective of texture of their parent material. In a Brown Solonetz (Peters 1973), Mg was the principal water-soluble cation; in a Gray Solonetz it was codominant with Na. Generally, the order was Na > Mg > Ca > K. In each soil, HCO_3 and Cl (in that order) were the other main anions present. Sodium adsorption ratio* is an index of sodium hazard; values greater than 10-15 will reduce the growth of most crops (Krogman 1973). Sodium adsorption ratios of the two upper horizons of the solonetz in this study were just within this range, whereas SAR values for the chernozem did not exceed 0.3.

Calcium-to-extractable-sodium ratio of the solonetz in this study was less than 10 for the Ap, Bnt, and Csk2 horizons (Table 3), indicating an undesirable ratio of ions in the soil solution (Toogood 1973). In contrast, the Ca/Na ratio was higher (25-29) in the chernozem, helping to explain why production of conifer stock has been better on this soil. Sodium as a percentage of total extractable cations was highest in the Ap and Bnt horizons (14 and 20%) and indicated that unsuitable Na levels were being approached. When Na exceeds 12-15% of exchangeable (equivalent to "extractable" in noncalcareous soil) cations, alkali conditions develop; soil structure tends to become blocky and undesirable because Na disperses the clay and drainage is impeded (United States Salinity Laboratory Staff 1954). The Csk2 horizon contained crystals of sodium sulphate, but Na as a percentage of extractable cations declined in favor of Ca because like Csk1, this horizon was also calcareous.

The matrix of extractable cations in the solonetz used in this experiment was similar to that of a Brown Solonetz developed on glacial till and a Black Solonetz developed on lacustrine sediments. In both soil subgroups, exchangeable hydrogen was present in the Bnt as well as the Ap horizons, but in this study it was found only in the Ap horizon on account

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* $SAR = Na/\sqrt{(Ca + Mg)/2}$, if Na, Ca, and Mg are expressed in me/ℓ.

of the alkaline Bnt horizon. However, extractable bases in the Ap and Bnt horizons of the solonetz in this study followed the order cited (Mg > Ca >> Na > K) for the Brown and Black Solonetzic soil subgroups (Peters 1973). For a Black Alkaline Solonetz and a Gray Solonetz, both of which developed on till, extractable bases in the Ah and Bnt horizons were in the following order: Ca > Mg >> Na > K. Differences between soil subgroups were influenced by groundwater chemistry and depth to the water table (Pawluk 1973). In all cases, including the solonetz in this study, the magnitude of extractable bases in Csk horizons was Ca > Mg >> Na > K, reflecting accumulation of carbonates and sulphates of calcium and magnesium. A fluctuating water table and low permeability coupled with evapotranspiration would affect the depth of accumulation of salts within the profile.

LEACHING OF SOLONETZIC SOIL

Amelioration of the soil through leaching with chemicals did not seem feasible judging from results in the laboratory. Leaching was very slow, and besides nursery water (control), only NH_4NO_3 and $(NH_4)_2SO_4$ solutions yielded enough leachate for analysis. However, the infiltration rate of these solutions was much greater than that of nursery water. The very slow movement of water and chemical solutions through the columns of soil was attributed primarily to the soil's high clay content (71-80%), which restricts movement of water because of the large percentage of small pores. In Alberta, Cairns and van Schaik (1968) reported ameliorative effects (water movement and structure) of $CaCl_2$, $MgCl_2$, NH_4NO_3, and $(NH_4)_2SO_4$ on the Ap and Bn horizons of a Black Solonetz set in metal columns. Differences in materials and methodology may explain some of the differences between the results of their experiment and the present one. Cairns and van Schaik (1968) used a coarser-textured soil (silt loam) and separate leaching columns for each of their two horizons, whereas segments containing each horizon were connected to form a model profile in this experiment. Bulk density of soil in their columns was not reported but it was probably lower than BD in this experiment (1.2 g/cm^3) because the columns, consisting of 100 g soil in a volume

of 276 cm^3, were saturated from the bottom prior to leaching. Such conditions could result in a greater percentage of large pores, increased capillary conductivity, and consequently, increased infiltration rate.

Movement of water through soil columns in this study was undoubtedly restricted by swelling that was observed (but not measured) as wetting progressed. van Schaik and Pawluk (1973) reported that the fine-clay fraction of Alberta solonetzic soils was high in montmorillonite, which swelled when saturated with sodium and wetted. This phenomenon would help to restrict water movement through closely packed fine-textured soil by blocking the smaller pores.

Salts such as NH_4NO_3, $(NH_4)_2SO_4$, $CaSO_4$, $FeSO_4$, and $Al_2(SO_4)_3$ have been suggested for use on saline and alkali soils (United States Salinity Laboratory Staff 1954). By replacing Na on the exchange complex of the clay, they improve structure through flocculation and increase the infiltration rate of water. However, the effectiveness of these compounds presupposes adequate movement of water to remove displaced Na from the profile. In this study, the replacing cations were not effective because small pore size and discontinuity of pores restricted water movement to a minimum. This problem is common in solonetzic soils of Alberta. Cairns and van Schaik (1968) found that downward movement of water was extremely slow even through the Ap horizon of a solonetzic soil. van Schaik and Pawluk (1973) reported that it took 2800 h for water to penetrate 30 cm of soil of a Black Solonetz Ah horizon and 3100 h to penetrate a similar depth of soil of the Bnt horizon. They also reported HC's of 0.7 and 0.6 cm/h for the Ah and Bnt horizons, respectively. Hydraulic conductivity was much lower (0.1 cm/h) in soil columns used in the present study and would explain the ineffectiveness of leaching as a method of amelioration.

Ammonium nitrate and ammonium sulphate percolated through the soil much faster than water, $CaSO_4$, $FeSO_4$, or $Al_2(SO_4)_3$, thus supporting the findings of Cairns and van Schaik (1968). However, leachate from both columns were high in dissolved salt even after 90 days, indicating that considerable leaching was still required. The ineffectiveness of $CaSO_4$ was

probably due initially to its low solubility, and consequently it would tend to precipitate within soil pores when SO_4-rich soil was encountered (common-ion effect). The application of gypsum ($CaSO_4 \cdot 2H_2O$) to ameliorate solonetzic soils in Alberta has not been successful primarily because of gypsum's low solubility (van Schaik and Pawluk 1973), whereas $CaCl_2$ improved water penetration considerably (Cairns and van Schaik 1968). Calcium chloride was not used in this experiment because of the detrimental effect of chloride ion on coniferous tree species (Edwards and Blauel 1976). Ferrous sulphate and aluminum sulphate were unsuccessful as ameliorants most likely because of low hydraulic conductivity of the soil.

OTHER METHODS OF AMELIORATION

The slow movement of water through this solonetzic soil indicated that chemical amelioration would be impractical under operational conditions at the nursery. Other methods of amelioration will have to be assessed. Deep plowing (40-60 cm) of solonetzic soils in Alberta has increased the yield of cereals and forage crops (Cairns 1962, Bowser and Cairns 1967, and Cairns 1967, and Cairns 1970). This practice brings Ca-rich soil from the Csk horizon into the A and B horizons, thus reducing the percentage of exchangeable Na in the root zone. The beneficial effect of deep plowing is also due to a more favourable microbiological environment (near-neutral pH) following the introduction of calcium carbonate into the Ap horizon (Cairns 1973). For production of conifer seedlings at the nursery, deep plowing might still not be profitable on account of the fine texture, although breaking up the subsoil would facilitate root penetration.

Installation of tile drainage and irrigation combined with application of $CaSO_4$ have been used successfully on medium-textured soils in southern Alberta (van Schaik and Milne 1962). This probably would not be feasible at Oliver on account of the undulating topography and the hard, compact, fine-textured subsurface horizons. If drainage is to be effective under such conditions, land levelling and close spacing of tile drains would be necessary. High capital cost would most certainly result in uneconomic production of conifer seedlings. Besides, land levelling in solonetzic

areas redistributed soil and crop variability without any significant increase in yield (Cairns 1973). Physical and chemical properties of this soil also make it unsuitable for irrigation. Krogman (1973) reported that, assuming favourable topography, irrigation as a method of amelioration may be feasible if HC is greater than 1.3 cm/h, SAR less than 10 to 15, and EC less than 4 dS/m. No horizon of the Black Solonetz at Oliver nursery met all of these criteria. High concentration of soluble salts in the nursery water would also limit the effectiveness of irrigation.

The best prospect for use of this land lies in the proper choice of tree species to be grown. Abraham and Bocskai (1971) reported that hardwoods (*Quercus* spp., *Salix* spp., *Ulmus* spp., *Fraxinus* spp., *Acer* spp., and *Populus* spp.) were more tolerant of alkali conditions than conifers. These species, except for *Quercus* spp., are already being grown successfully as shelterbelt stock throughout solonetzic areas of the nursery (Fields 11-25) and therefore should be continued. Nitrogen fertilization may improve tree growth, since N as NH_4NO_3 increased yield of forage crops on Black Solonetz soils in Alberta (Toogood 1973). Calcium nitrate was also suggested as a desirable N source (Cairns 1973), since Ca would tend to neutralize soil acidity and improve structure by replacing Na on the exchange complex.

CONCLUSIONS

1. The Black Solonetzic soil in Field 11-25 at the Oliver nursery is unsuitable for producing conifer seedlings because of its clayey texture; hard, compact, sodium-enriched B horizon; and extremely low hydraulic conductivity.
2. Amelioration of this soil through leaching in the presence of chemicals does not seem feasible because of the low hydraulic conductivity.
3. Other methods of amelioration are likely to prove impractical or uneconomical in a conifer nursery operation.

RECOMMENDATIONS

1. Fields 11-25 should be used exclusively for production of hardwood stock.

2. Irrigation should be regulated to avoid flooding or ponding.
3. An adequate fertilization program should be maintained. Calcium nitrate and ammonium nitrate are desirable sources of nitrogen.
4. Production of conifer seedlings, if required, should be confined to the portion of the nursery that is nearer to the building complex.

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